Foundations of Modern Networking

SDN, NFV, QoE, IoT, and Cloud

By: William Stallings

Chapter 11

QoE: User Quality of Experience

Definition of Quality of Experience

- Combining the previous concepts and definitions, the definition of QoE that reflects broad industry and academic consensus is:

> Quality of experience (QoE) is the degree of delight or annoyance of the user of an application or service. It results from the fulfillment of his or her expectations with respect to the utility/ enjoyment of the application or service in the light of the user's personality and current state.

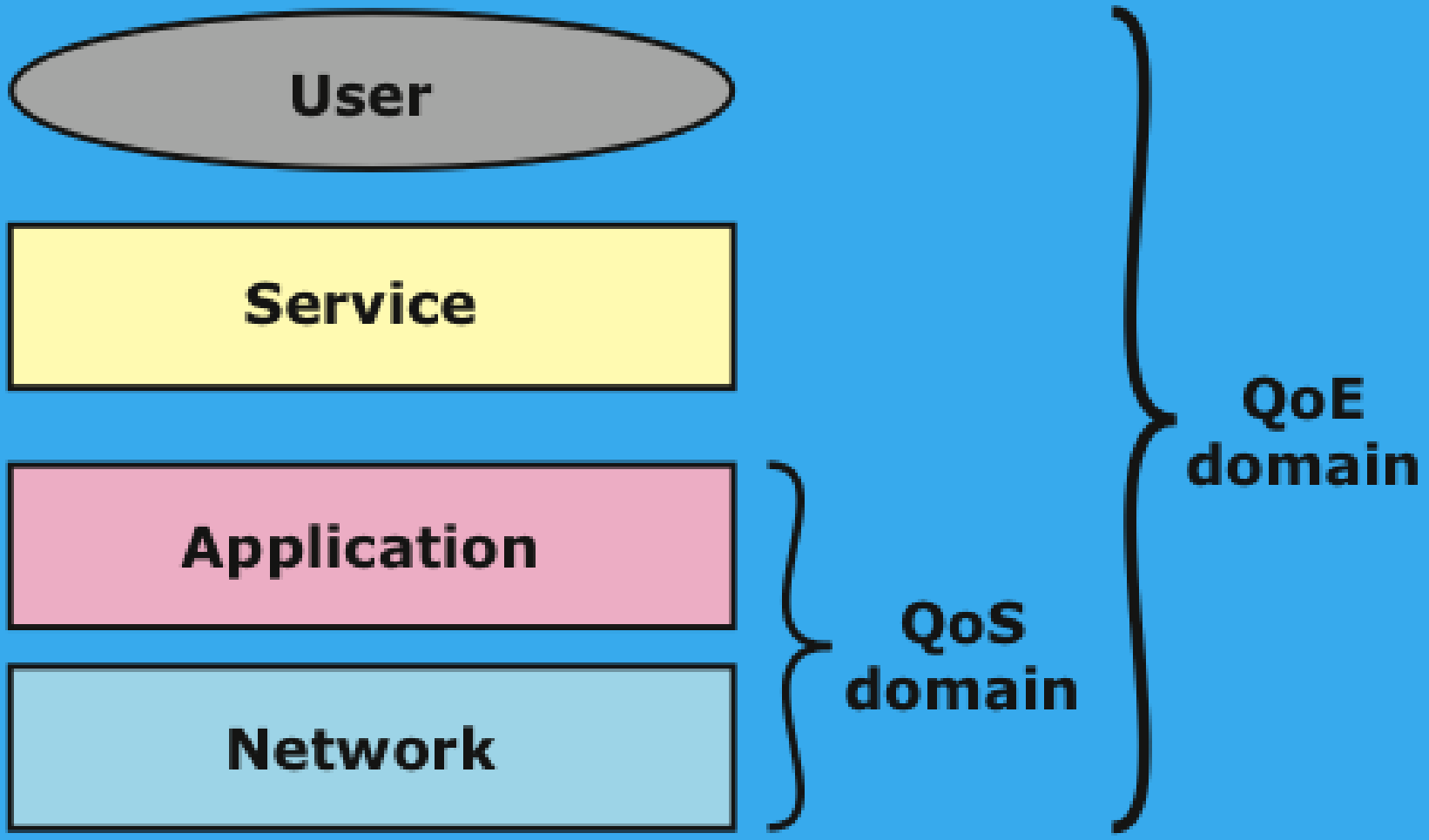


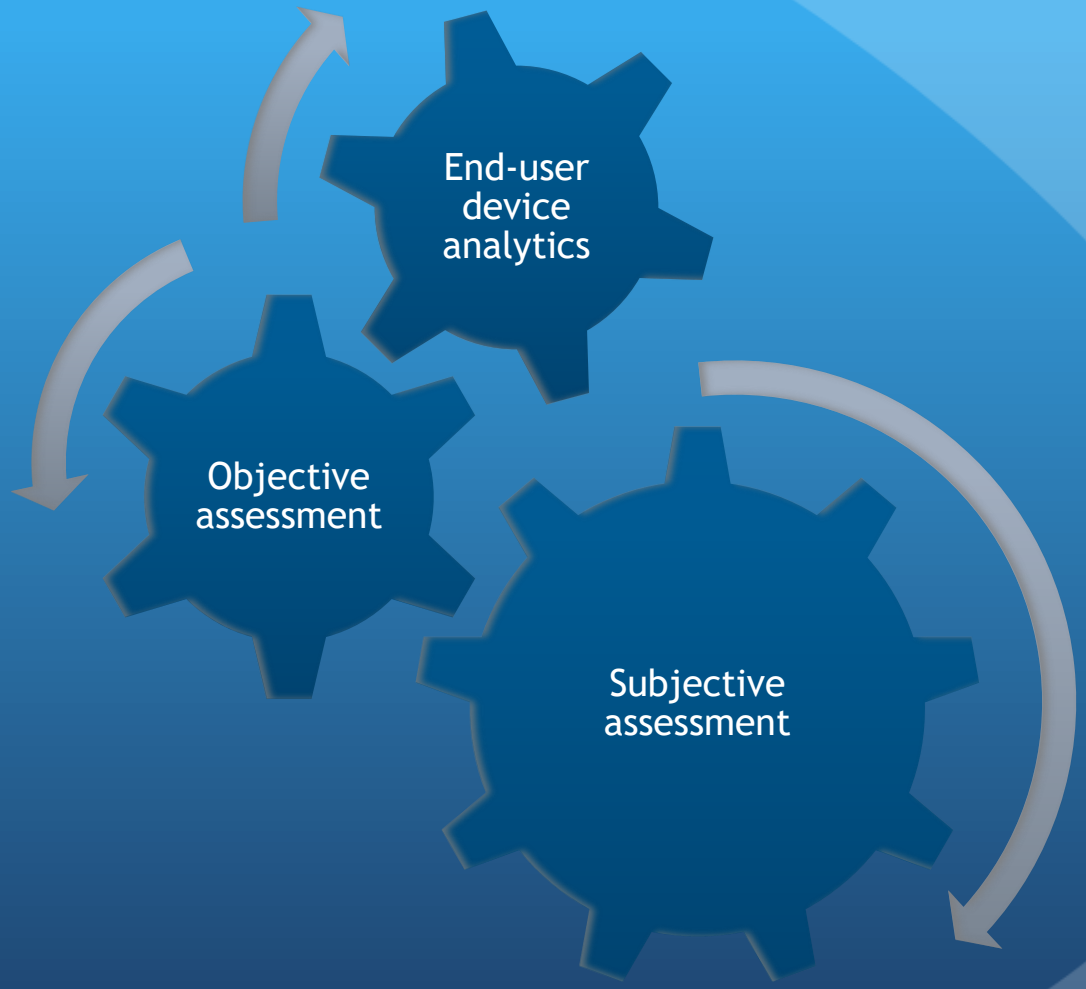
Figure 11.4 QoS/QoE Layered Model

Factors Influencing QoE

- QoE must be studied and addressed by taking into account both technical and nontechnical factors
- Key factors are:

User demographics	Type of device	Content
Connection type	Media (audio-visual) quality	Network
Usability	Cost	

Measurements of QoE



QoE measurement methods

Subjective Assessment

- For subjective assessment of QoE, experiments are carefully designed to a high level of control so that the validity and reliability of the results can be trusted
- A methodology to obtain subjective QoE data might consist of the following phases:
  - Characterize the service
  - Design and define test matrix
  - Specify test equipment and materials
  - Identify sample population
  - Subjective methods
  - Analysis of results

Objective Assessment

- For objective assessment of QoE, computational algorithms provide estimates of audio, video, and audiovisual quality as perceived by the user
- The goal of any objective model is to find the optimum fit that strongly correlates with data obtained from subjective experiments
- A methodology to obtain objective QoE data might consist of the following phases:
  - Database of subjective data
  - Preparation of objective data
  - Objective methods
  - Verification of results
  - Validation of objective model

End-User Device Analytics

- Real-time data such as the connection time, bytes sent, and average playback rate are collected by the video player application for each video viewing session and fed back to a server module when the data is pre-aggregated and then turned into actionable QoE measures
- Some of the metrics reported for per-user and aggregate viewing sessions include startup delay, rebuffering delays, average bit rates, and the frequency of bit rate switches
- Operators may be inclined to associate viewer engagement levels with their QoE because good QoE usually make viewers less likely to abandon a viewing session
- The definition of viewer engagement may have different meanings for different operators and context:
  - First, operators might like to know which viewer engagement metrics affect QoE the most to guide the design of the delivery infrastructures
  - Second, they might also like to quickly identify and resolve service outages, and other quality issues
  - Finally, they would like to understand their customers' demographics within a demographic region so that resources can be strategically dimensioned

Table 11.2: Five Point MOS Rating Scale.

Score	Label
5	Excellent
4	Good
3	Fair
2	Poor
1	Bad

Applications of QoE

- The practical application of QoE can be grouped into two areas based on the main usage:

Service QoE monitoring

- Service monitoring allows the support teams to continually monitor the quality experienced by the end users of the service
- A service alert message might be sent to the support teams when QoE falls below a certain threshold value, as this will allow the support teams to quickly identify and resolve service outages and other QoE issues
- This approach might introduce high monitoring overheads for a per-user scenario

QoE-centric network management

- The ability to control and optimize the user experience when QoE degradation issues arise is the holy grail of QoE network management
- Two approaches in which QoE-centric management can be exploited:
  - In the first approach, a set of QoS measurement values together with the appropriate assumptions, are used in computing the expected QoE for a user
  - In the second approach, which is somewhat the opposite of the first, a target QoE for a user together with the appropriate assumptions is used to produce estimates of the required QoS values

End of Chapter 11

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Chapter 12

Network Design Implications of QoS and QoE

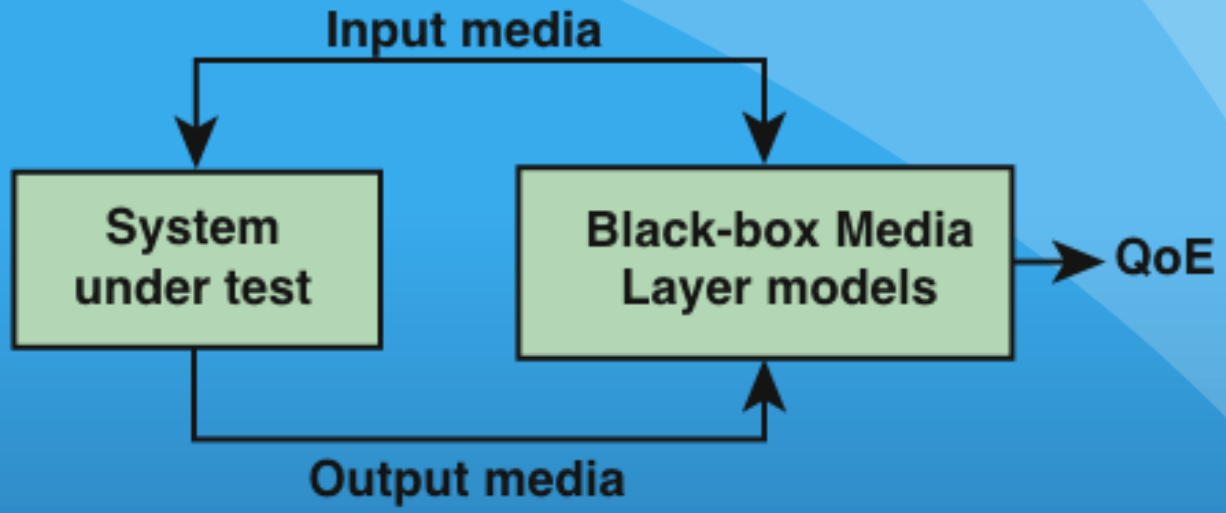
Classification of QoE/QoS Mapping Models

- Mathematical models used to define the empirical relationship between QoS and QoE are referred to as QoE/QoS mapping models or quality models
- The application area of QoE/QoS mapping models depends mostly on their inputs
- QoE/QoS mapping models can be classified according to their inputs into three categories:

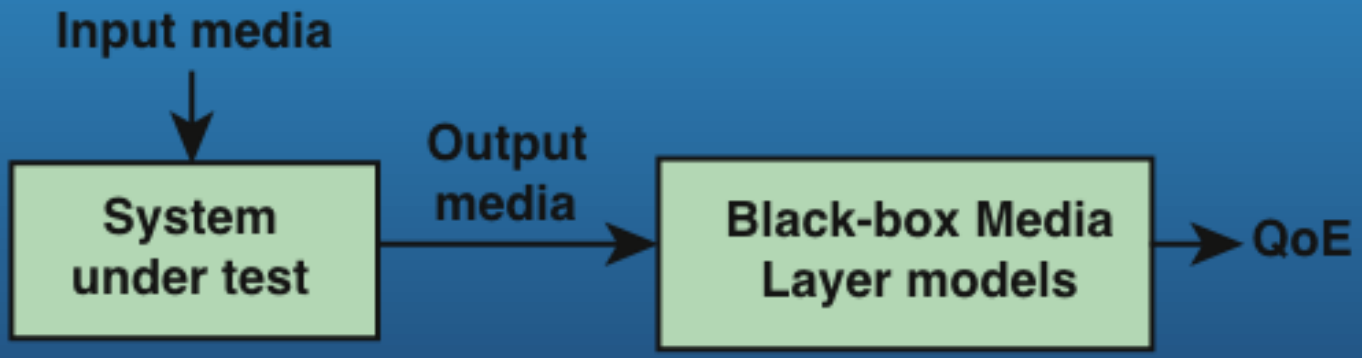
Black-box media-based models	Glass-box parameter-based models	Gray-box parameter-based models

Black-Box Media-Based QoS/QoE Mapping Models

- Rely on the analysis of media gathered at system entrance and exit
- They account implicitly for the characteristics of examined media processing system
- Classified into two categories:
  - Double-sided or full-reference quality models
  - One-sided or no-reference quality models



(a) Double-sided or full-reference quality models



(b) One-sided or no-reference quality models

Figure 12.1 Black-Box Media-Based QoS/QoE Mapping Models

Glass-Box Parameter-Based QoS/QoE Mapping Models

- The glass-box parameter-based models may operate offline or online according to the availability of characterization parameters at a given measurement instant
- The characterization parameters include noise, packet loss, coding scheme, one-way delay, and delay jitter
- The glass-box parameter-based models are generally less accurate and coarser than black-box media-based ones

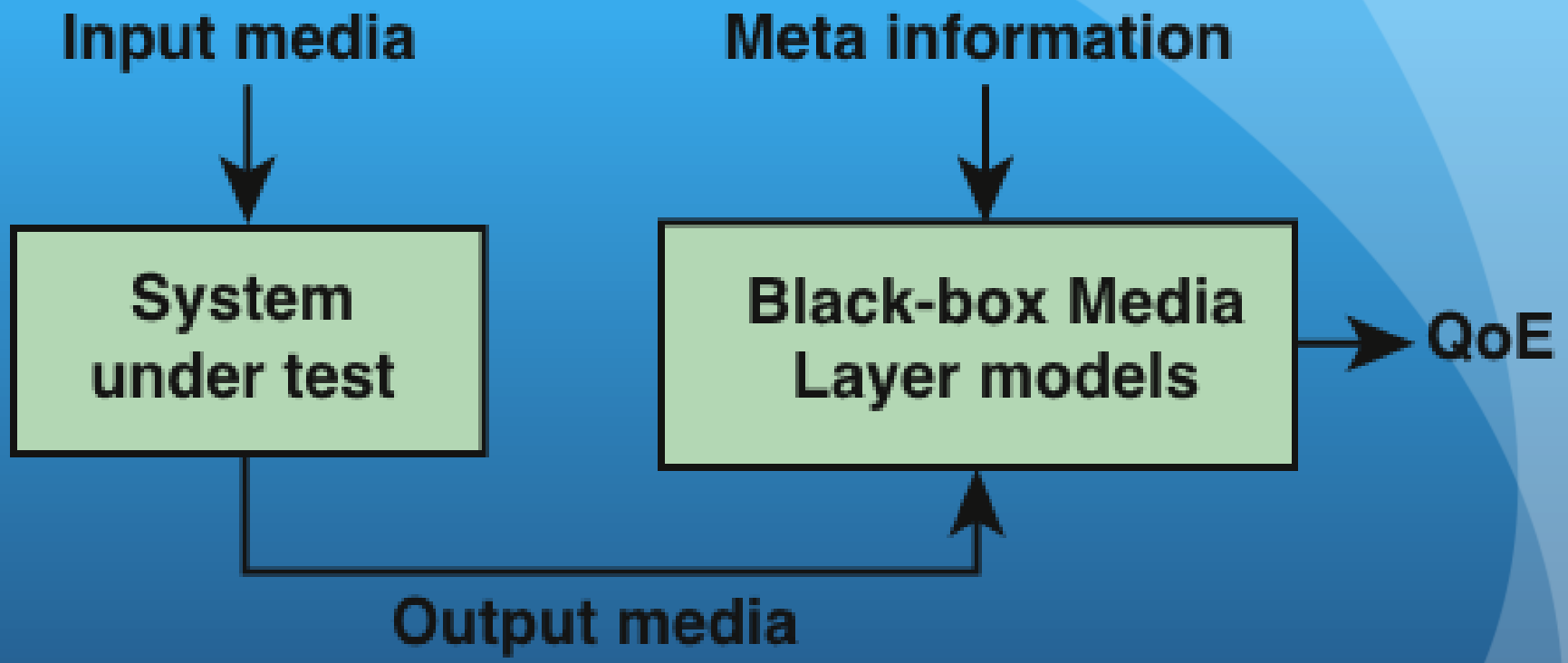


Figure 12.2 Gray-Box QoS/QoE Mapping Models

Tips for QoS/QoE Mapping Model Selection

The following checklist of five items can aid in the selection of a QoS/QoE mapping model:

- Which types of operations am I considering?
- Which parameters do I have? Can I access the signals, the contents, the packet payload or the header?
- Do I expect specifications and usage conditions to use a given mapping model?
- How much precision do I need?
- Do I have all inputs available for selected mapping models?

IP-Oriented Parameter-Based QoS/QoE Mapping Models

- IP networks carry clean media content from a server to a destination using a flow of media packets composed of a header and a payload
- Parameters gathered at network layer, in addition to application layer, are easily accessible at run time on user devices
  - This enables measuring QoE at run time using online glass- or gray-box parameter-based quality models
- The QoE over IP-based networks are time-varying
  - This characteristic leads to considering instantaneous and overall QoE

QoE/QoS Mapping Models for Video Services

- Network layer
  - The network layer QoS/QoE mapping models rely solely on NQoS metrics gathered from the TCP/IP stack except for the application layer
- Application layer
  - Besides NQoS parameters, application layer QoE/QoS mapping models use metrics gathered at application layers
  - They can account for the user behavior while interacting with a given video content

Actionable QoE over IP-Based Networks

- Actionable QoE refers to all techniques and mechanisms enabling to concretely measure and utilize QoE metrics
- Actionable QoE goes beyond QoE definition and measurement toward QoE exploitation
- An actionable QoE solution strongly depends on the underlying system and services characteristics
- Actionable QoE solution works over multiplane architectures that integrate data, control, and management planes
- Two solutions may be used to achieve actionable QoE:
  - System-oriented actionable QoE solution
  - Service-oriented actionable QoE solution

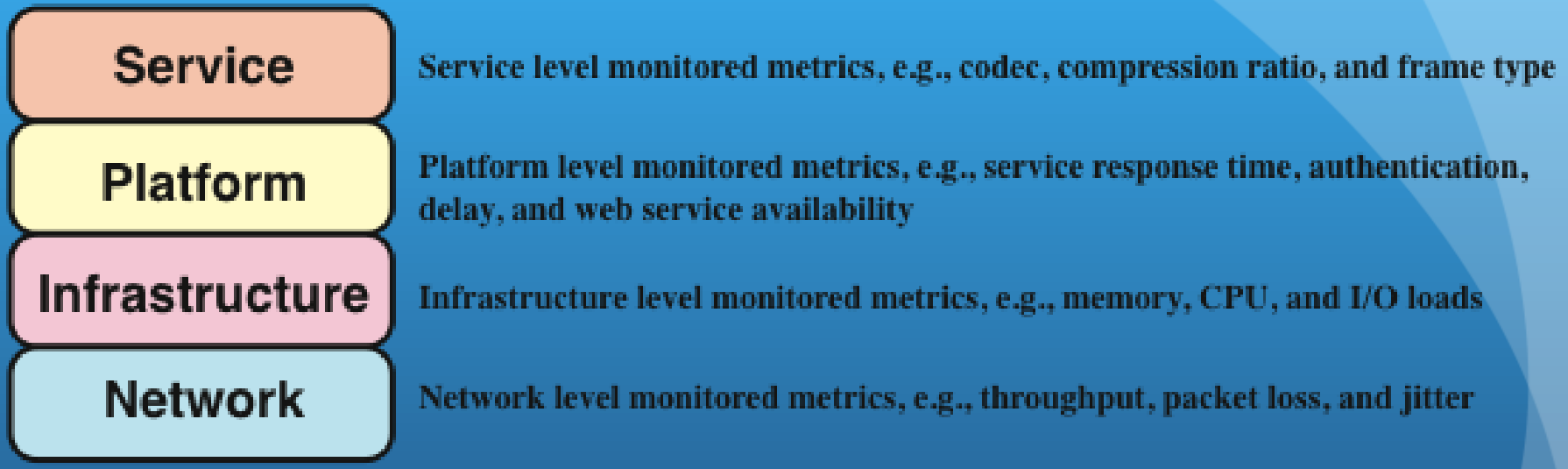


Figure 12.5 A Classification of Monitoring Solutions

QoE-Agent

- The architecture of QoE-agent is based on a layered definition of APIs that enable convenient grouping of different factors that influence QoE
- The six layers are:
  - Resource
    - Composed of dimensions representing the characteristics and performance of the technical system(s) and network resources used to deliver the service
  - Application
    - Composed of dimensions representing application/service configuration factors
  - Interface
    - Represents the physical equipment and interface through which the user is interacting with the application
  - Context
    - Related to the physical context, the usage context, and the economic context
  - Human
    - Represents all factors related to the perceptual characteristics of user
  - User
    - These factors encompass all aspects of humans as users of service or applications

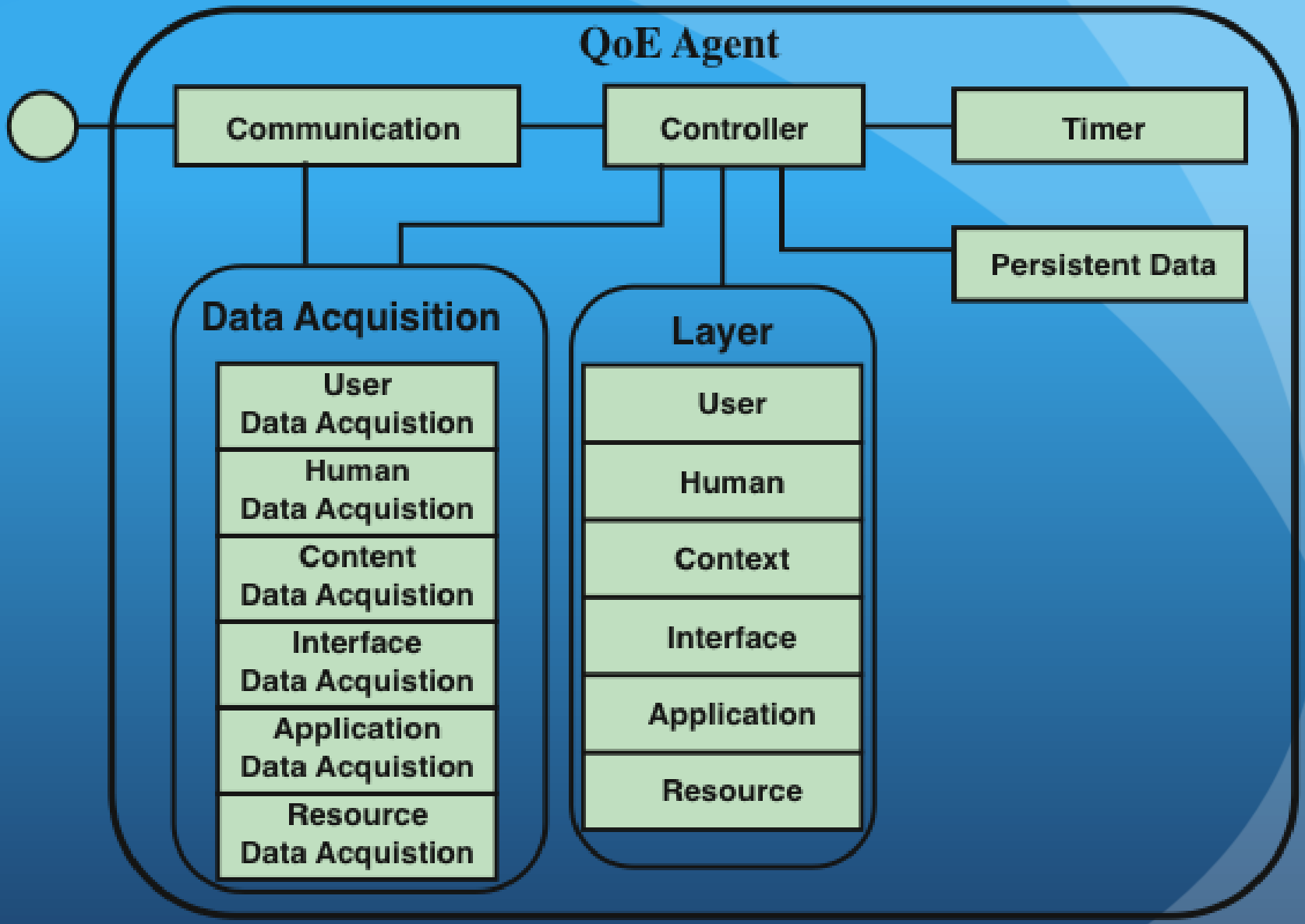


Figure 12.9 A Maximum Co-Located QoE Agent (Generic QoE Agent)

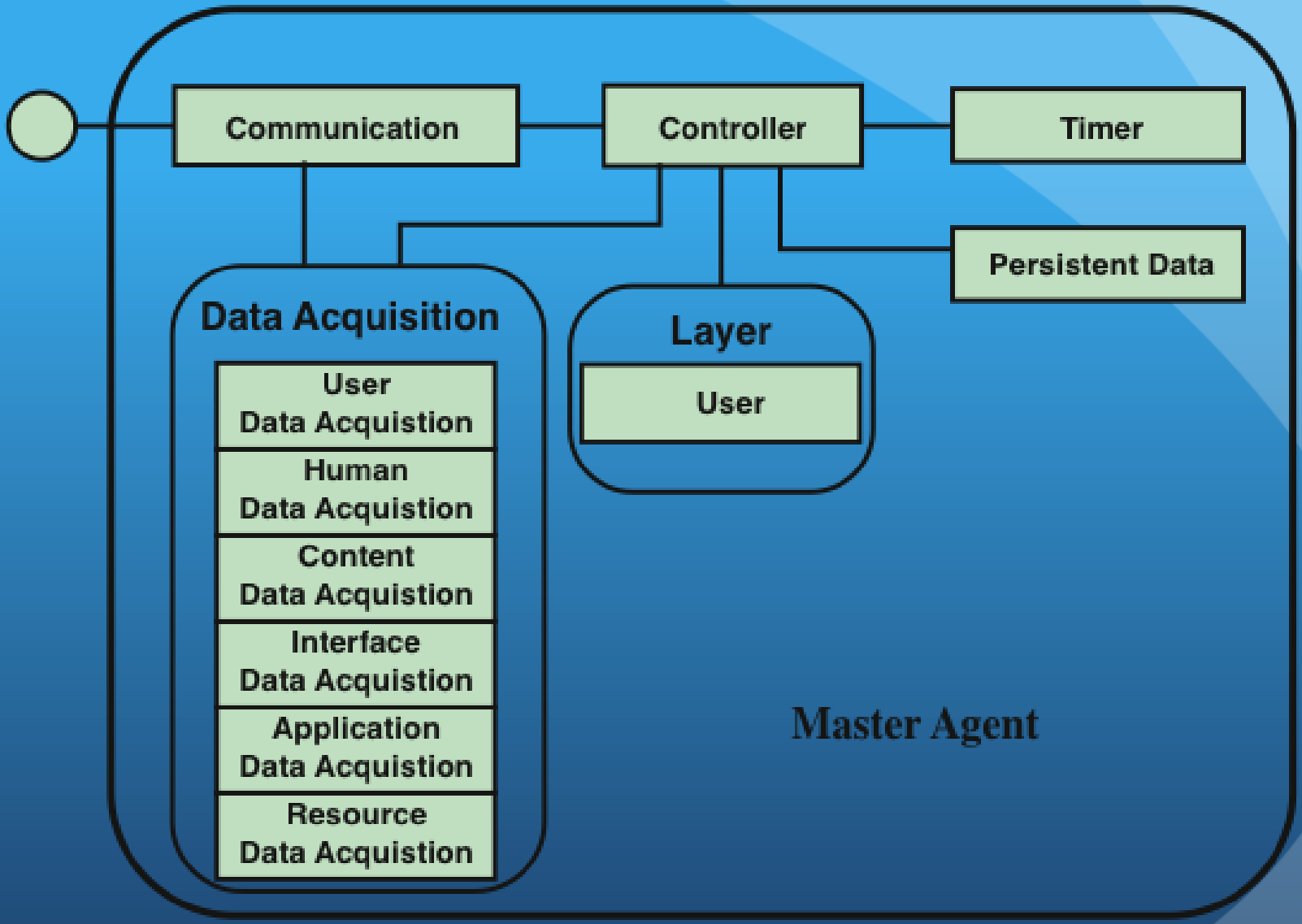


Figure 12.10 A Minimum Master Agent
(with only user model)

QoE-Based Network and Service Management

- QoE-Based Management of (VoIP) calls
  - The goal is to maintain a constant QoE level during a whole packet voice session transmitted over time-varying quality IP networks
  - Typically, QoE measurement probes following one glass-box parameter-based model are installed on VoIP endpoints
  - They collect at run time atomic KPIs, which are transformed and given as inputs to a QoE/QoS mapping model
  - After a new measure of QoE values is received, a QoS controller adjusts the reconfigurable network parameters within a delivery path, such a queuing allocation and congestion thresholds
  - A simple policy consists of allocating more network resource if the QoE value is less than a targeted QoE value

End of Chapter 12